Prospect of dual-purpose legumes for livestock production through dry season irrigation

Terry Ansah, Davie Kadyampakeni and Richard Appoh

Produced by International Water Management Institute
Published by International Institute of Tropical Agriculture

February 2017
www.africa-rising.net

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment. http://africa-rising.net/

This document was made possible with support from the American people delivered through the United States Agency for International Development (USAID) as part of the US Government's Feed the Future Initiative. The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of USAID or the U.S. Government

Table of contents

Introduction

Livestock production is an important component of the livelihoods of people in the tropics including Northern Ghana. The population of cattle, sheep, and goat in Ghana is 1.39, 3.21, and 3.63 million, respectively, with about 74.4% of the cattle, 36.5% of the sheep, and 34.5% of the goat found in the three northern regions of Ghana (LPIU 1997; Oppong-Anane 2006), The major source of forage for feeding livestock in most developing countries is natural pasture. The quantity and quality of natural pasture is influenced by season with very poor quality forage reported during the dry season. Very low live body weight has been reported for ruminant livestock grazing natural pasture without supplementation in the dry season (Ansah et al. 2016 Konlna et al. 2012; Avornyo et al. 2015).

Crop residues and agro-by-products serve as important feed supplement for ruminant livestock production, especially during the dry season (Ansah et al. 2016). In the Upper East Region of Ghana, residues for cowpea and groundnuts are sold on the market for the supplementation of ruminant livestock feed (Konlan et al. 2016. These residues are often generated from fields cultivated in the wet season. The high demand for the leguminous crop residues offers great opportunity for upscaling the cultivation of these legume crops.

The cultivation of these leguminous crops in the dry season under irrigation is one way of ensuring the sustainable supply of quality crop residue in the dry season.

Cowpea (*Vigna unguiculata*) is a legume cultivated throughout most tropical countries and it serves as a source of food for humans and feed for livestock. It is reported to be a drought-tolerant plant, can be cultivated on poor soils, and also fixes nitrogen into the soil (Grings et al. 2012). Its drought-tolerant property makes it ideal for cultivation under dry season irrigation. These properties may differ depending on variety (Singh et al. 1997).

Irrigation scheduling determines when and how much water is to be applied to a crop (Broner 2005). It has the potential of regulating the time, energy, and money used for irrigation. The effect of different irrigation schedules on the grain yield of cowpea has been conducted with significant differences being reported in some cases for yield (Dadson et al. 2005; Mbagwu and Osuigwe 1985). The difference in water use by plants depends on irrigation amount and frequency (Adekalu and Okunade 2006). Mbagwu and Osuigwe (1985) concluded that irrigating cowpea at field capacity every two days resulted in the optimum grain yield.

Literature on the effect of watering regime or drought stress on the nutritive value of cowpea fodder is virtually nonexistent. However, drought stress was found to lead to a decrease in acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations in some forage legumes (Peterson et al. 1992). Seguin et al. (2002) and Nakayama et al. (2007) reported increases in structural cell wall concentrations and water-soluble carbohydrate when some forage legumes were exposed to drought stress.

Several varieties of cowpea have been released to farmers by various crop research institutes for upscaling. Most of these varieties have not been evaluated for their fodder quality. Songotra and Padi-Tuya are among the cowpea varieties released by the Savanna Agricultural Research Institute (SARI) as drought tolerant, pest resistant, and high yielding. Yields of about 1.6 to 2.5 tons per hectare were recorded for these varieties. The important role crop residues and agro-by-products play in the nutrition of ruminant livestock forms the basis for the evaluation of grain yield, residue yield, and quality of cowpea cultivated under different irrigation regimes.

Farmers in the Nyangua community of the Kasena-Nankana District are familiar with dry season cultivation of food crops with irrigation from groundwater sources. The cultivation of cowpea has been practiced under irrigation by these farmers, particularly women, for production of leafy vegetables. This often compromises grain yield since most leafy vegetables from cowpea are harvested before flowering. Cultivation of dual-purpose cowpea (grain and fodder) will be more appealing to most livestock farmers since they will not have to sacrifice the grain.

A pilot study was conducted to determine the growth, grain yield, and fodder yield of two dual purpose cowpea under irrigation.

Materials and methods

The study was conducted in Nyangua in the Kasena-Nankana District of the Upper East Region, Ghana. A total of 16 crop-livestock farmers were randomly selected for this study. The coordinates and elevation of each plot are shown in Table 1.

Table 1. Coordinates and elevation of experimental plots.

No.	North	West	Elevation (m)
1	10.93833	001.06438	191
2	10.93784	001.06348	190
3	10.93713	001.06298	189
4	10.93705	001.06317	192
5	10.93744	001.06301	195
6	10.93913	001.06555	182
7	10.94201	001.06597	186
8	10.94326	001.06526	195
9	10.94321	001.06535	190
10	10.93913	001.06555	189
11	10.93808	001.06417	187
12	10.94321	001.06535	190
13	10.93804	001.06420	188
14	10.94187	001.06235	195
15	10.94596	001.06356	197
16	10.94049	001.06425	189

Two varieties of cowpea (Songotra-IT97K-499-35 and Padi-Tuya) were purchased from the IITA seed outgrowers in Ghana and distributed to the farmers.

Four out of the 16 main plots were grazed by free-ranging sheep and goats in the third week. The results reported in this study are from 12 main plots.

Each farmer ploughed and prepared a minimum of a 5 m × 5 m plot for the cultivation. The farmers were randomly assigned to two main treatments in a 2 × 3 factorial design (table 2). The treatments were the two varieties of cowpea and three irrigation schedules (T0, T2-day, and T4-day intervals). Two separate subplots were randomly selected from each farmer's main plot. One plot was used for taking measurements on the irrigation schedule while the other plot served as a control where the farmer applied water using their own traditional method. An area of 1 m × 1 m was selected from each subplot for measurement of agronomic data and sampling for nutrient analysis.

The experiment was laid as a 2 × 3 factorial in a randomized complete block design with three replicates per treatments (table 2). The factors were the two cowpea varieties (Padi-Tuya and Songotra) and the three irrigation schedules (T0, T2, T4-day interval). Irrigation schedule T0 was the farmers own practice while schedules 2 and 4 were chosen following the recommendation of Mbagwu and Osuigwe (1985) who found that when cowpea was irrigated at full field capacity in a sandy soil in Nigeria, the highest grain yield was obtained at 2-day intervals as compared to the 4-day watering regime. Since there was no literature on the scheduling for cowpea for the study area, we chose to compare the two irrigation schedules of Mbagwu and Osuigwe (1985) to the farmer practice.

Table 2. Layout of treatments on the plots.

Block 1	Block 2	Block 3
Padi-Tuya T0	Songotra T0	Songotra T0
Padi-Tuya T2	Songotra T2	Padi-Tuya T2
Padi-Tuya T4	Songotra T4	Padi-Tuya T0
Songotra T0	Padi-Tuya T0	Songotra T2
Songotra T2	Padi-Tuya T2	Songotra T4
Songotra T4	Padi-Tuya T4	Padi-Tuya T4

Prior to flowering, a uniform irrigation schedule of 5133 m^3/ha was applied at 2-day intervals in accordance with the farmers traditional practice. The control plots (T0) were irrigated with a total of 5500 m^3/ha at 2-day intervals post-flowering till harvest. An average of 1625.0 m^3/ha of water was applied from flowering to harvest for T2 and 812.5 m^3/ha for T4 after estimating the water requirement using FAO CROPWAT 8.0 (Allen et al. 1998). T2 and T4 received 100% crop water requirement using CROPWAT.

The crop water requirements, effective rainfall, and irrigation requirements for cowpea were estimated using FAO CROPWAT 8.0. The estimations were done using climatic data from CLIMWAT 2.0 (Munoz and Grieser 2006; Mekonnen and Hoekstra 2010) for the Navrongo agroclimatic station. Other inputs required for CROPWAT include soil physical properties of the experimental site such as texture, field capacity, permanent wilting point, available water capacity, infiltration rates of the soil, crop type, effective rooting depth, and information on growth stages to period of maturity and number of days to maturity. Tables 3 and 4 represent a summary of information on soil physical properties and estimated crop water requirements of cowpea, respectively.

Table 3. Soil data for the experimental site at Nyangua in Ghana.

Property	Description/concentration
Texture	Sandy loam
Field capacity	0.143
Permanent wilting point	0.057
Saturation	0.457
Saturated hydraulic condition (cm/hr)	8.0
Available water	85.83 mm/m
Average infiltration rate (cm/hr)	3.3

Table 4. Crop water requirement at various growth stages of cowpea.

Month	Days	ETc* mm/day	ETc (subplot area 6 m^2) L/plot/day	Total volume per stage L/plot/stage
December	8	6.02	36.12	288.96
January	31	12.06	72.36	2243.16
February	27	14.38	86.28	2329.56
Total	66	32.46	194.76	4861.68

*ETc: Crop evapotranspiration under standard conditions.

The crops were sprayed with Sunhalothrine® insecticide at 500 ml/ha prior to flowering. After flowering, Lion-force® insecticide was also applied at a rate of 1.5 L/ha.

Agronomic data were collected and these included days to 50% germination and flowering, weekly plant height, and canopy cover. After harvesting, grain, pod husk, and haulm yield were determined for each subplot. The haulm was evaluated for crude protein, NDF, ADF, ash, metabolizable energy, in vitro gas production, and in vitro organic matter digestibility. The haulms were milled (2 mm) and analyzed for their crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and ash concentration. The milled samples were analyzed for ash following the standard procedure of AOAC (2000). Approximately 2 g of the haulm of each treatment was placed in porcelain crucibles and combusted in a furnace at a temperature of 600 ^{o}C for 4 h to determine the ash concentration.

The nitrogen (N) content was determined using the Kjeldahl method (AOAC 2000). Crude protein was computed from the total nitrogen by multiplying the N by 6.25. The method of Van Soest et al. (1991) was used to determine the neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentration. The NDF was determined exclusive of residual ash with sodium sulfite and α-amylase while ADF was determined exclusive of residual ash using the Ankom^{200} fiber analyzer.

The in vitro gas production technique of Theodorou et al. (1994) was adopted. Approximately 200 mg of oven dried samples from each treatment was weighed into 50 ml test tubes and incubated in McDougall's buffer under anaerobic condition. The gas production was measured using a digital manometer at 3, 6, 12, 24, and 48 h. The gas readings were then fitted to the exponential curve of Ørskov and McDonald (1979) without an intercept using SigmaPlot 10th edition (Systat Software Inc. 2006). The degradation parameters (b and c) were derived from exponential model.

$$Y = b\,(1 - e^{-ct})$$

Where Y = gas volume at time t (mL)
b = asymptotic gas production (%)
t = time (h)
c = fractional rate of gas production (mL/h)

The in vitro digestible organic matter (DOM) was calculated using the equation DOM (%) = 16.49 + 0.9042 GP + 0.0492 CP + 0.0387ash by Menke and Steingass (1988) while the metabolizable energy was calculated using the equation ME (MJ/kg DM) = 2.20 + 0.136 *GP + 0.057 *CP according to Menke et al. (1979).
where,
GP = gas production (ml/200 mg DM at 24 hr)
CP = Crude protein (g/kg DM).

The water use productivity was computed for both grain and fodder by dividing the grain or fodder by the amount of water used. The data was analyzed as a two-way ANOVA in RCBD using GenStat 11th edition. The means were separated using Tukeys at 5%.

Results and discussion

The total volume of water used among the three irrigation schedules ranged between 5945.8 and 10450 for the farmer practice (T0) and irrigation schedule T4 (Fig. 1).

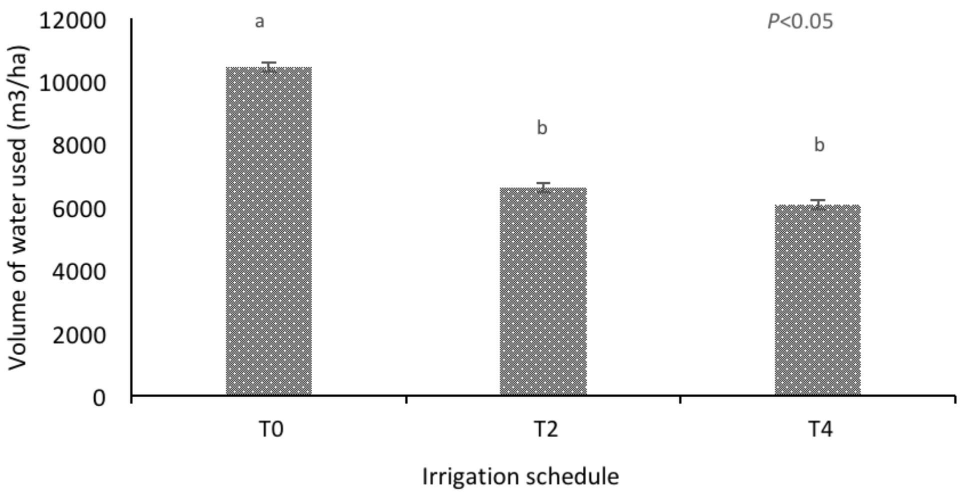

Figure 1. Volume of water (m^3/ha) applied from planting to harvesting (58 days).

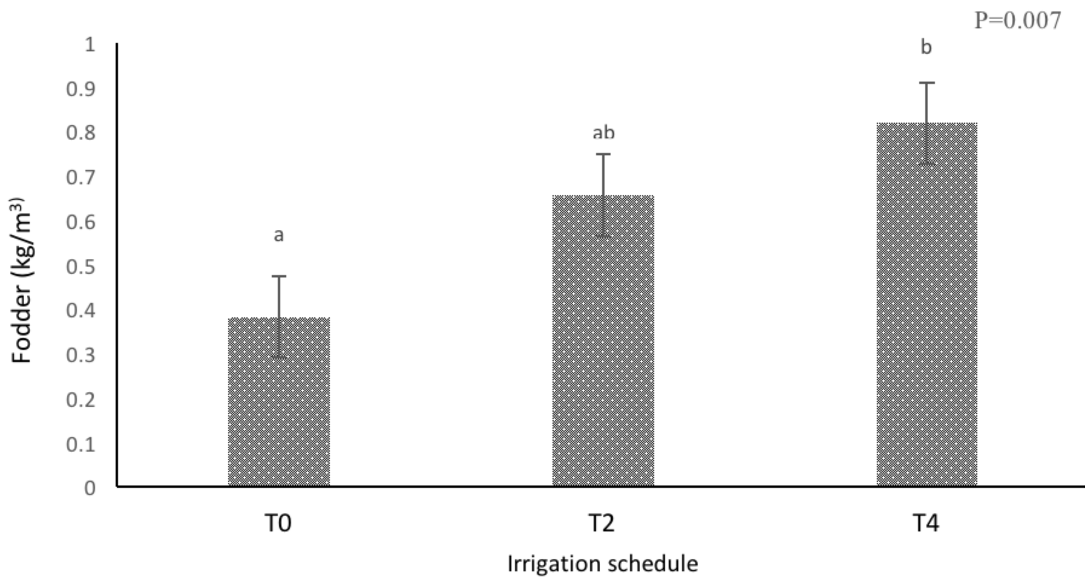

Figure 2. Fodder yield/m^3 of used as affected by the irrigation schedule.

The effects of the two-way interaction (var × IS) on the agronomic parameters measured were not significantly different. There was a significant effect of irrigation schedule on the ratio of fodder to water use or crop water productivity (Fig. 2). Fodder to water use ratio was significantly higher in T2 and T4 than in the farmer practice (T0). A similar trend was observed in the cowpea grain yield to water use but the difference was not significant (Figs. 3 and 4). The difference observed was due to the limited quantity of water used in irrigating T2 and T4 as compared to T0. Drought, together with high temperature and long day, has been found to substantially reduce cowpea productivity (Nielsen and Hall 1985; Dow El-Madina and Hall 1986; Patel and Hall 1990). Drought stress affects plant cell enlargement and rate of cell division and this will often lead to reduced leaf area and ultimately affect photosynthesis (Slayter 1967; Turner and Begg 1978). Reduced rate of photosynthesis could negatively affect growth, and grain and fodder yield. The lack of difference in the grain and fodder yield relative to the treatments suggests that irrigation schedule T4 could be adopted without significantly affecting these parameters. However, in the present study, the prolonged irrigation schedule compared favorably with the shorter schedules with the prolonged shedule performing better than the shorter schedule in some parameters. Farmers could save on cost of water use during dry season irrigation by adopting one of the prolonged irrigation schedules assuming no serious water deficits occur to compromise biomass yield.

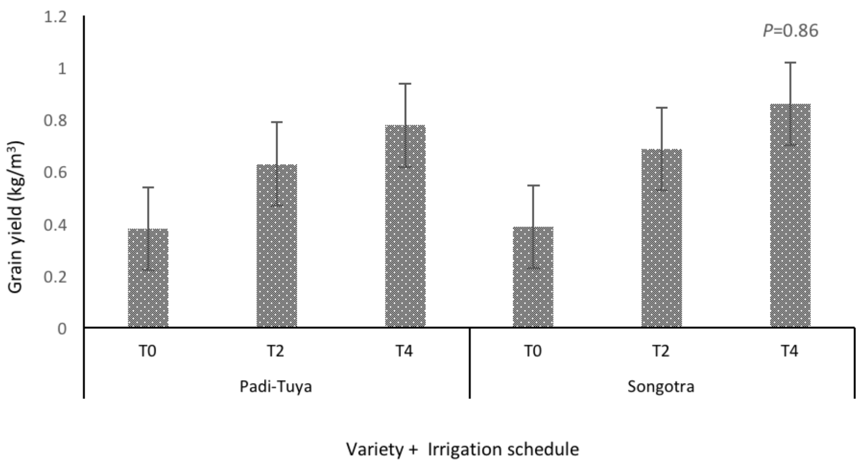

Figure 3. Mean cowpea grain yield per water use as affected by variety and irrigation schedule.

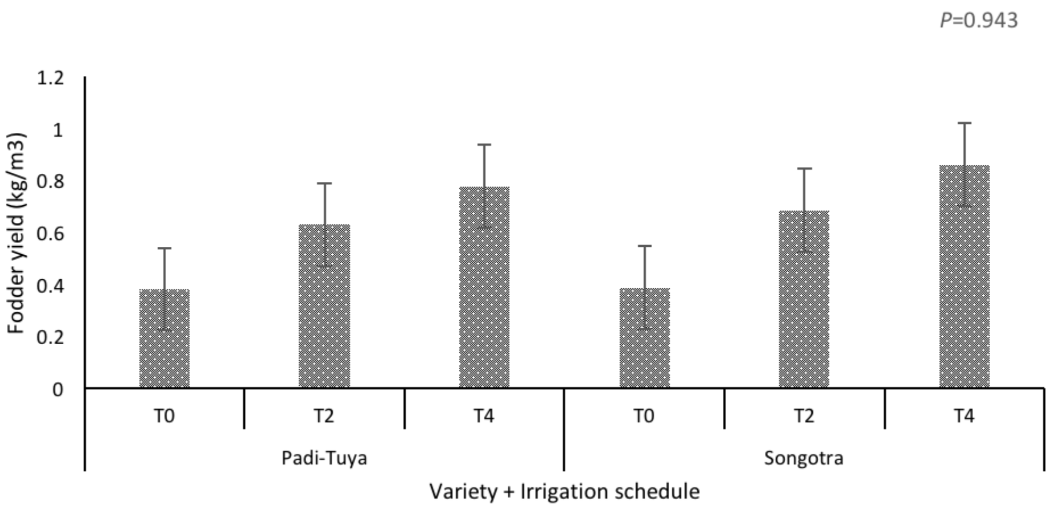

Figure 4. Mean fodder yield (haulm + pod husk) as affected by variety and irrigation schedule.

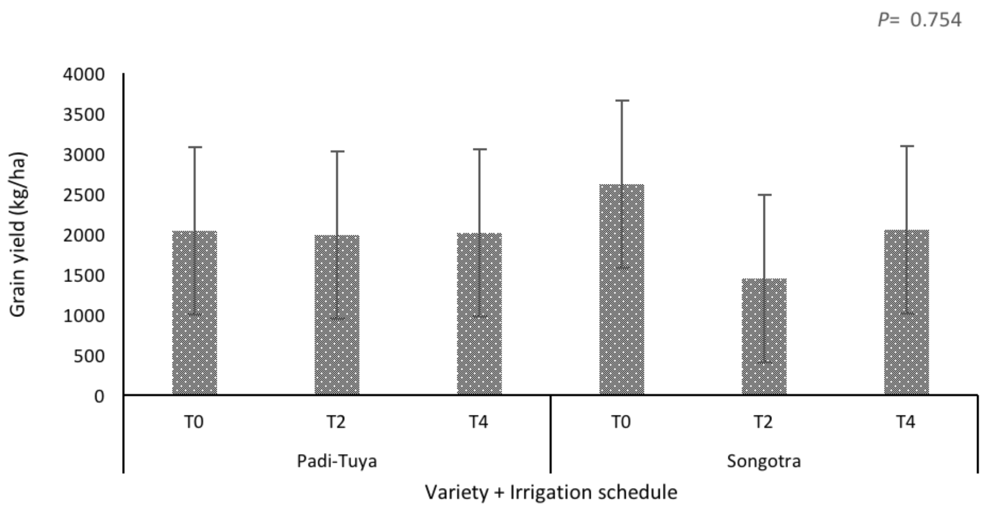

Figure 5. Mean cowpea grain yield as affected by variety and irrigation schedule.

The total cowpea grain and fodder yield did not differ as a result of the two-way interaction of main effects (Figs. 5 and 6). The highest (P = 0.745) cowpea grain yield was found in Songotra under irrigation schedule T0 while the highest (P = 0.80) fodder was observed in the same variety Songotra under irrigation schedule T4. Even though there was no significant difference, the results suggest that Songotra has a better grain and fodder yield potential than Padi-Tuya. The lack of significant effect of the prolonged irrigation schedule on the grain and fodder yield suggests that these varieties could be adopted for cultivation as a climate change adaptation measure.

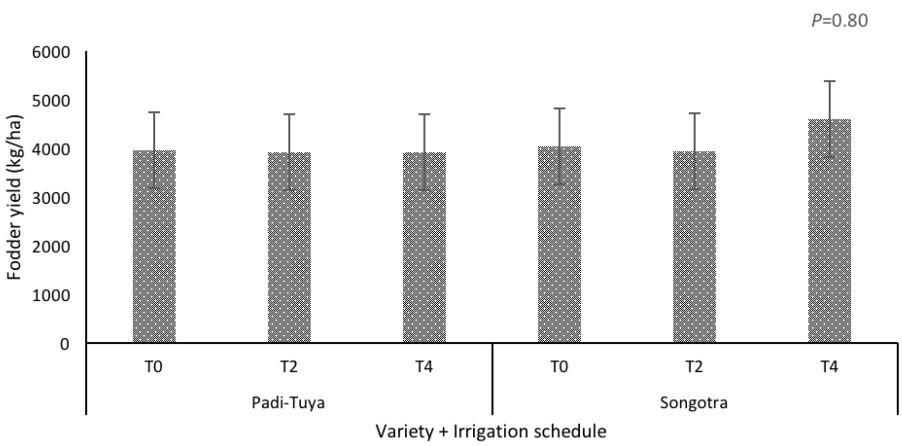

Figure 6. Mean pod husk yield as affected by variety and irrigation schedule.

Table 5. Mean (%) chemical composition of haulms of two cowpea varieties irrigated at three different schedules.

Parameter	Padi-Tuya			Songotra			SED	Var	IS	Var × IS
	T0	T2	T4	T0	T2	T4		*P. value*	*P. value*	*P. value*
DM	84.0	87.0	89.3	88.0	85.0	88.0	2.4	0.87	0.24	0.20
CP	13.5	12.7	13.8	17.1	14.8	15.8	2.5	0.10	0.68	0.87
Ash	14.0	14.7	14.3	17.0	16.0	16.7	1.6	0.04	0.99	0.78
NDF	34.0^{ab}	26.9^{a}	43.0^{b}	30.7^{ab}	41.2^{b}	32.1^{ab}	5.9	0.99	0.46	0.02
ADF	20.1	20.0	20.7	24.0	24.2	24.9	3.4	0.06	0.94	0.99
IVOMD	40.4	41.4	41.5	43.1	43.6	41.8	2.4	0.23	0.86	0.76
ME (MJ/kg DM)	11.7	11.4	11.9	13.7	12.7	12.9	1.4	0.11	0.82	0.85

*DM; Dry matter; NDF: neutral detergent fiber; ADF: acid detergent fiber; CP: crude protein; IVOMD: in vitro organic matter digestibility; ME: metabolizable energy; Var: variety; IS: irrigation schedule; SED: standard error of difference; means with different superscript are significantly different at P < 0.05.

The variety and irrigation schedule interaction did not significantly affect any of the nutrient composition and digestibility with the exception of NDF (Table 5). The lowest NDF (P = 0.02) was recorded in variety Padi-Tuya with irrigation schedule T2 while the highest was observed in Songotra with irrigation schedule T2. This result is an indication that the deposition of cell wall carbohydrate in the two varieties was influenced differently by the same irrigation schedule. The finding in Padi-Tuya with irrigation schedule T4 supports the report of Seguin et al. (2002) who found an increase in cell wall carbohydrate when drought stress was imposed. The NDF and ADF recorded in the present study were lower than what was reported previously in similar varieties cultivated under rainfed irrigation with increasing levels of phosphate fertilizer application (Ansah et al. 2016). The low NDF and ADF reported in the present study could enhance voluntary feed intake and digestibility of the fodder when fed to ruminants (Hopkins and Wilkins, 2006; Moorby et al. 2006).

The in vitro organic matter digestibility recorded for the treatments was similar to that in an earlier report by Ansah et al. (2016) for the same varieties under rainfed conditions. The metabolizable energy for all the treatments was found to be above the daily requirement of 4.7 MJ/kg for growing lambs gaining 0–50 g/day (McDonald et al. 2011).

In vitro gas production did not differ significantly. There was a general increase in gas production with increase in time, suggesting that microbial degradation of the haulms was not negatively affected by the treatments (Table 6).

Table 6. Mean (mL/2 g DM) in vitro gas production of haulms of two cowpea varieties irrigated at different schedules.

Time (h)	Padi-Tuya			Songotra			SED	Var	IS	Var × IS
	T0	T2	T4	T0	T2	T4		*P. value*	*P. value*	*P. value*
3	3.0	5.2	3.2	2.8	3.5	2.6	1.1	0.22	0.10	0.61
6	5.4	7.7	5.6	5.0	6.2	5.0	1.1	0.20	0.05	0.75
9	7.4	10.0	8.1	7.1	8.5	7.2	1.4	0.28	0.11	0.85
12	9.4	11.9	10.4	9.1	10.9	9.3	1.8	0.43	0.22	0.94
24	12.4	15.8	14.5	12.8	15.1	12.2	2.3	0.52	0.21	0.71
36	14.0	17.7	17.0	14.7	17.4	14.5	2.5	0.63	0.22	0.66
48	14.8	20.5	18.0	15.7	18.4	15.4	2.7	0.42	0.10	0.61

Var: variety; IS: irrigation schedule; SED: standard error of difference; *P* value: $P < 0.05$.

Conclusion and recommendation

The study revealed that the two cowpea varieties can be cultivated as dual-purpose legumes for grain and fodder. Variety Songotra had a slightly superior fodder quality than Padi-Tuya. T2 and T4 saved considerable quantity of water compared with farmers’ practices. In addition, higher grain and fodder yields were produced per liter of water in T2 and T4 than under farmers’ practices (T0). This indicates that advising smallholder farmers how much and when to apply water is essential to increase crop water productivity, and save water and labor.

Acknowledgement

This work was supported with funds from the USAID-funded Feed the Future Africa RISING project in northern Ghana. Additional funding was provided by the CGIAR Research Program on Water, Land Ecosystems for travel support and staff time.

References

Adekalu, K.O. and Okunade, D.A., 2006. Effect of irrigation amount and tillage system on yield and water use efficiency of cowpea. Communications in Soil Science and Plant Analysis. 37: 225-228.

Ansah, T., Algma, H.A. and Dei H.K. 2016. Variety and phosphate fertilizer dose effect on nutrient composition, in vitro digestibility and feeding value of cowpea haulm. Journal of Animal Science and Technology. 58:19-

AOAC International. 2000. Official methods of analysis of Association of Analytical Communities (AOAC) International. 17th edition. Gaithersburg, MD, USA, Association of Analytical Communities.

Al-Jamal, M.S., T.W. Sammis, S. Ball, and D. Smeal. 1999. Yield-based, irrigated crop coefficient. Applied Engineering in Agriculture 15(6): 659–668.

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and Drainage Paper 56. FAO, Rome.

Ansah, T., H.A. Algma, andH.K. Dei. 2016. Variety and phosphate fertilizer dose effect on nutrient composition, in vitro digestibility and feeding value of cowpea haulm. Journal of Animal Science and Technology 58: 19.

Avornyo, F.K., A. Ayantunde, M.T. Shaibu, S.P. Konlan, and N. Karbo. 2015. Effect of feed and health packages on the performance of village small ruminants in Northern Ghana. International Journal of Livestock Research 15: 91–98.
Broner, I. 2005. Irrigation scheduling. Page 1 in Crop Series on Irrigation. Colorado State University Cooperative Extension Factsheet No. 4.704.

Dadson, R.B., F.M. Hashem, I. Javaid, J. Joshi, A.L. Allen, and T.E. Devine. 2005. Effect of water stress on the yield of cowpea (*Vigna unguiculata* L. Walp.) genotypes in the Delmarva Region of the United States. Journal of Agronomy & Crop Science 191: 210–217.

Dow El-Madina, I.M., and A.E. Hall. 1986. Flowering of contrasting cowpea (*Vigna unguiculata* L. Walp.) genotypes under different temperatures and photoperiods. Field Crops Research 14: 87–104.

Grings, E.E., S.A. Tarawali, M. Blummel, A. Musa, C. Fatokun, S. Hearne and O. Boukar, 2012. Cowpea in Evolving Livestock Systems. In: Innovative Research along the Cowpea Value Chain, Boukar, O., O. Coulibaly, C. Fatokun, K. Lopez and M. Tamo (Eds.). International Institute of Tropical Agriculture, Ibadan, Nigeria.

Hopkins, A. and R.J. Wilkins. 2006. Temperate grassland: key developments in the last century and future perspectives. Journal of Agricultural Science Cambridge 144: 503–523.

Konlan, S.P., Ayantunde, A.A., Addah, W. and Dei, K.H. 2016. Evaluation of feed resource availability for ruminant production in Northern Ghana. International Journal of Livestock Research, 6 (6): 39-59.

LPIU (Livestock Planning and information Unit). 1997. 1996 livestock census. Ministry of Food and Agriculture. Accra. 5 p.

Mbagwu, J.S.C. and J.O. Osuigwe. 1985. Effects of varying levels and frequencies of irrigation on growth, yield, nutrient uptake and water use efficiency of maize and cowpeas on a sandy loam ultisols. Plant and Soil 84: 181–192.

McDonald, P., R.A. Edwards, J.F.D. Greenhalgh, C.A. Morgan, L.A. Sinclair, and R.G. Wilkinson. 2011. Animal nutrition, Seventh edition, Pearson Education Limited, England.

Mekonnen, M.M. and A.Y. Hoekstra. 2010. Mitigating the water footprint of export cut flowers from the Lake Naivasha basin, Kenya, Value for Water Research series No. 45, UNESCO-IHE, Delft, The Netherlands.
Menke, K.H. and H. Steingass. 1988. Estimation of the energetic feed value obtained from chemical analysis and in vitro gas production using rumen fluid. Animal Research and Development 28: 7–55.

Menke, K.H., L. Raab, A. Salewski, H. Steingass, D. Fritz, and W. Schneider. 1979. The estimation of the digestibility and metabolizable energy content of ruminant feedstuffs from the gas production when they are incubated with rumen liquor in vitro Journal of Agricultural Science Cambridge 92: 217–222.

Moorby, J.M., R.T. Evans, N.D. Scollan, J.C. Mac Rae, and M.K. Theodorou. 2006. Increased concentration of water-soluble carbohydrate in perennial ryegrass (*Lolium perenne* L.). Evaluation in dairy cows in early lactation. Grass Forage Science 61: 52–59.

Munoz, G. and J. Grieser 2006. FAO of UN CLIMWAT database, Food and Agriculture Organization, Rome, Italy,www.fao.org/nr/water/infores_databases_climwat.html. (Accessed December 2016).

Nakayama, N., Saneoka, H., Moghaieb, R.E.A., Premachandra, G.S. and Fujita, K. 2007. Response of growth, photosynthetic gas exchange, translocation of ^{13}C-labelled photosynthate and N accumulation in two soybean (*Glycine max* (L). Merrill) cultivars to drought stress. International Journal of Agriculture and Biology. 9: 669-674.

Nielsen, C.L. and E. Hall. 1985. Responses of cowpea (*Vigna unguiculata* (L). Walp.) in the field to high night air temperature during flowering 11. Plant responses. Field Crops Researcg 10: 181–191.

Oppong-Anane, K. 2006. Country pasture/forage resource profiles. Animal Production Directorate, Ministry of Food and Agriculture. Accra North, Ghana.

Ørskov, E.R. and McDonald, I., 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rates of passage. Journal of Agricultural Science 92: 499–503.

Patel, P.N. and A.E. Hall. 1990. Genotypes variation and classification of cowpea for reproductive responses to high temperatures under long photoperiods. Crop Science 30: 614–621.

Peterson, P.R., Sheaffer, C.C. and Hall, M.H. 1992. Drought effects on perennial forage legume yield and quality. Agronomy Journal. 84: 774-779.

Seguin, P., Mustafa, A.F. and Sheaffer, C.C., 2002. Effects of soil moisture deficit on forage quality, digestibility and protein fractionation of Kura clover. Journal of Agronomy and Crop Science. 188: 260-266.

Singh, B.B., Chambliss, O.L and Sharma B. 1997. Recent Advances in Cowpea Breeding. In: Advances in Cowpea Research (Singh, B.B, Mohan Raj D.R., Dashiell K.E. and Jackai L.E.N. (Eds.). Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan. Nigeria. pp. 30-49.

Slayter, R.O. 1967. Plant water relationships. Academic Press, New York. 366p.

SYSTAT software Inc - SSI. Sigmaplot for Windows, version 10, 2006. http://www.systat.com.products/sigmaplot.

Theodorou, M.K. A.W. Barbara, M.S. Dhanoa, A.B. McAllan, and J. France. 1994. A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. Animal Feed Science and Technology 48: 185–197.

Turner, J.R. and J.E. Begg. 1978. Response of pasture plants to water deficits. In Plant relations in pasture, edited by J.R. Wilson. CSIRO, Melbourne, Australia.

Van Soest, P.J., J.B. Robertson and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74: 3583–3597.

Annexes

Annex 1. Effect of variety and irrigation schedule on some agronomic parameters.

Parameter	Padi-Tuya			Songotra			SED	Var	IS	Var × IS
	T0	T2	T4	T0	T2	T4		*P.* value	*P. value*	*P. value*
Canopy cover (%)	86.3	80.0	84.3	86.7	76.7	91.7	7.9	0.76	0.22	0.63
Plant height (cm)	37.5	35.8	37.8	37.1	30.8	48.6	6.6	0.64	0.14	0.26
Grain yield (kg/h)	2033.0	1983.0	2017.0	2617.0	1450.0	2050.0	1037.6	0.96	0.72	0.75
Haulm yield (kg/h)	3042.0	3117.0	2833.0	3517.0	3417.0	3733.0	620.1	0.15	0.99	0.79
Pod husk yield (kg/h)	925.0	800.0	1083.0	517.0	517.0	867.0	367.0	0.18	0.46	0.93
Grain: Haulm	0.7	0.7	0.8	0.9	0.4	0.5	0.4	0.70	0.75	0.66
Grain: Husk	2.8	2.7	2.3	2.5	3.0	2.6	0.8	0.82	0.77	0.82
Grain/m^3	0.19	0.32	0.40	0.25	0.25	0.39	0.16	0.94	0.33	0.86
Fodder/m^3	0.38	0.63	0.78	0.39	0.69	0.86	0.16	0.60	0.007	0.94

Var: Variety; IS: irrigation schedule; SED: standard error of difference; *P.value* : $P < 0.05$.

Annex 2: Selected Photos

Photo 1. Prepared plots with sown cowpea.

Photo 2. Cowpea plant at 50% germination.

Photo 3. Cowpea plant at 50% flowering.

Photo 4. Harvested cowpea after 58 days.